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Using Modeling and Simulation to Graphically Display the Interaction of the Fire and the Extinguishing Agent

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The U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC) uses state-of-the-art modeling and simulation techniques as an integral part of its Simulation and Modeling for Acquisition, Requirement, and Training (SMART) effort. This paper will address how we applied these powerful tools to accurately depict how Halon-alternative agents react in a military vehicle.

Armored vehicle technology has an order of precedence that must be taken into account in today's vehicle designs, they are to not be: detected, acquired, hit, penetrated, or most importantly, killed. If munitions do make it to penetration, then, in order to protect soldiers from fires inside vehicle compartments, an extinguishing system must be used. Today's modern armored vehicles are equipped with high-speed fire sensors that can, within milliseconds, trigger the valves on the pressurized fire suppression bottles to quickly extinguish a potentially deadly fire.

The most popular and effective suppression gas has been Halon 1301. However, research has shown that Halon 1301 is an Ozone Depleting Chemical (ODC). In a search for environmentally friendly Halon-alternatives many variables must be manipulated such as bottle pressure, nozzle placement, nozzle design, distribution manifolds, shape of interior space, and exposure time to toxic gases in order to make the replacement agent as effective and safe as Halon 1301.

An armored vehicle that is penetrated has very little time to keep the fire from expanding. The fire needs to be suppressed as soon as possible. An adequate time to suppress the fire is approximately 0.2 seconds, which can be accomplished if nozzles are placed optimally. This short time is necessary to maintain safe concentrations of gaseous agent and toxic gases. It is the job of today's modeling and simulation software to help the system designer efficiently place the fire suppressant agent nozzles.

It was determined that an innovative approach needed to be taken in order to investigate this problem. As such, subject matter experts from the Communication Electronics Command (CECOM) and TARDEC were formed. TARDEC brought to the table its extensive program experience in developing and using Halon alternatives. Programs that accumulated a great deal of

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test data and experience in the performance, characteristics, and behavior of various agents, as well as toxicology concerns. CECOM's expertise is in fire suppression modeling. The team determined that the approach they would use to investigate this problem would be to leverage TARDEC's earlier work, and use the numerical techniques used in the model to spin-off of the electronics cooling modeling that CECOM was conducting. The team felt that the use of today's state-of-the-art visualization tools would facilitate understanding and solving the problem. It was determined that the CAVE Automated Virtual Environment (CAVE) hardware and software was best suited to make this happen effectively and efficiently. The team decided to perform four different configurations of nozzle placement, and then a 3D visualization result of the Halon Alternative agents would be experienced in the CAVE's virtual environment. It was determined that FM-200 would be the extinguishing agent with which these experiments would be conducted[1].

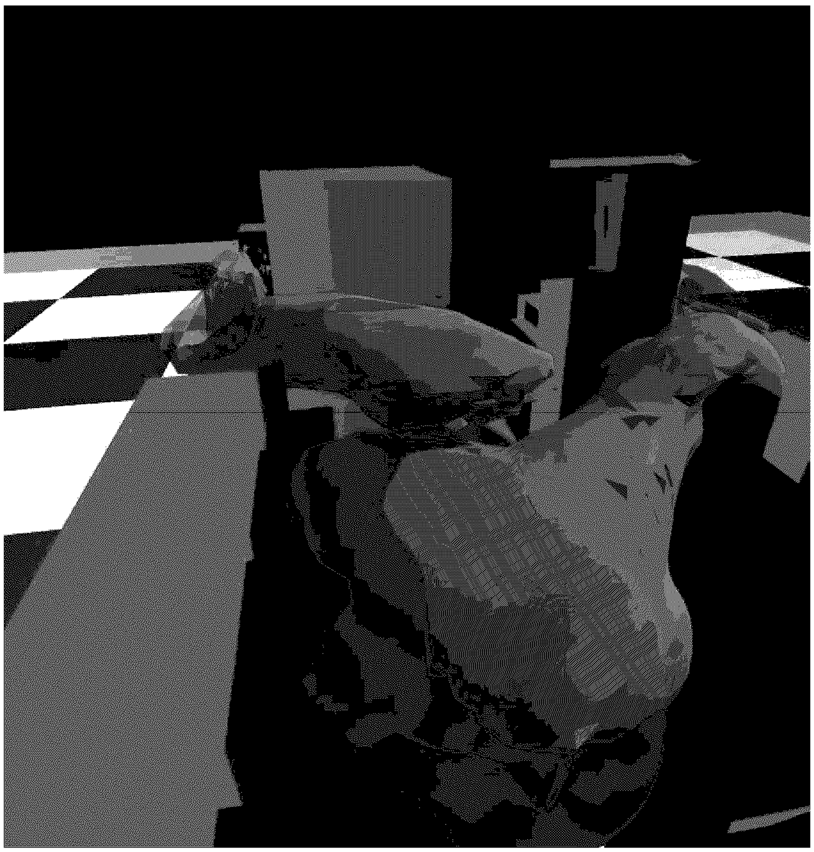

Figure 1: Interaction of Flame with Extinguishing Agent

The original output was generated using the TASCFLOW computational fluid dynamics code licensed by AEA Technology. It is a structured, multi-block code that was initially tailored to predict combustion in gas turbine engine combustors, where a spray of jet fuel (or JP8 in the M1 turbine engine) is ignited in the combustion chamber for gas turbine engines. Enhancements specific to the Army's needs had to be included. The fire suppression component was another module that had to be coded. CECOM led this effort.

[1] FM-200 is also known as HFC-227ea or heptafluoropropane, while its full chemical designation is 1,1,1,2,3,3,3-heptafluoropropane.

Three years ago (when this data was processed) 200,000 grids took a week of processing with a 500 MHz Alpha CPU. Now a 660,000-grid solution can be solved in 3 days on a high end PC. CPU-intense analysis of the fire is necessary due to the large number of 3-D coordinates that must be processed; those of the fire from ignition to extinguishment and those of the extinguishing agent from the nozzle until dissipation. For example, the two sections of the fire-extinguishing agent in figure 1 are comprised of over 17,500 nodes. We proposed a method of taking many consecutive time-step "snapshots" from beginning to end in order to present this data graphically by showing the vehicle system, the soldiers, the flame, and the extinguishing agent in separate colors to make it easy to analyze the interaction of the flame and the extinguishing agent throughout the simulation (shown in Figure 1; red is flame, blue is the extinguishing agent) by using a Virtual Reality Modeling Language (VRML) output to translate into our CAVE. VRML was chosen since it was determined to be the easiest modeling standard to translate the TASCFLOW "spreadsheet data" into usable graphics data. Tcl scripting language was used extensively in order to remove things like the texture information inherent in the VRML frames, but not used in our CAVE-formatted files.

The CAVE is a multi-person, room-sized, high-resolution, surround-sound, projection-based virtual reality (VR) system. The CAVE was designed from the beginning to be a useful tool for scientific visualization; the goal was to help scientists achieve discoveries faster, while matching the resolution, color and flicker-free qualities of high-end workstations. The illusion of immersion is created by projecting 3D computer graphics into a 2.5 meter cube composed of display screens that surround the viewer on the left, right, front, and bottom (see Figure 2). It is coupled with head and hand tracking systems to produce the correct stereo perspective and to isolate the position and orientation of a 3D input device. A sound system provides audio feedback. The viewer explores the virtual world by moving around inside the cube and grabbing objects with a three-button, wand-like device. Unlike users of the video-arcade type of VR system, CAVE dwellers do not wear helmets to experience VR. Instead, they put on lightweight stereo glasses and walk around inside the CAVE as they interact with virtual objects. Multiple viewers often share virtual experiences and easily carry on discussions inside the CAVE, enabling researchers to exchange discoveries and ideas. One user is the active viewer, controlling the stereo projection reference point, while the rest of the users are passive viewers.

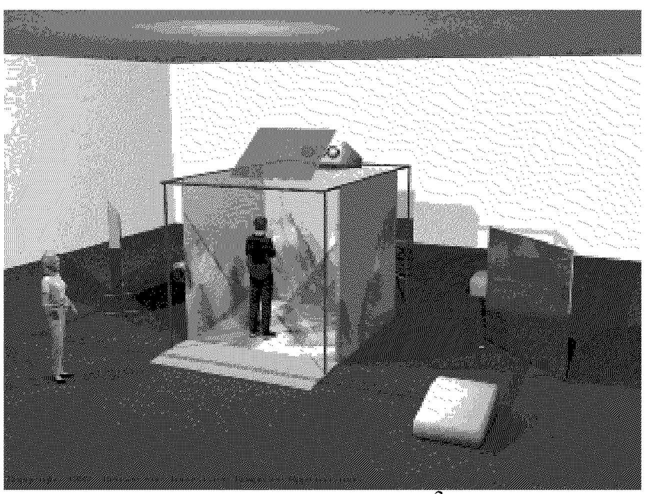

Figure 2: a CAVE[2]

[2] Figure 2 illustrates a generic CAVE, courtesy of the CAVERNUS Image Gallery, which can be found at: http://archive.ncsa.uiuc.edu/VR/cavernus/GALLERY/Gallery.html

The observer can walk anywhere in this cube and with the 3-dimensional mouse "walk" around the complete model, in our case a tank that was over 6m long. This gave the engineers and users a better understanding of how the extinguishing system reacted with the four suppression system configurations tested. For example, while watching the "playback" of the second configuration it was at first considered a success since no flame affected the soldiers in the rear section of the vehicle. But as one "walked" into the driver's section it was noticed that the bulk of the fire was pushed into this compartment; this configuration was quickly eliminated.

Figure 3 shows the actual CAVE used at TARDEC. A Silicon Graphics Onyx-2 workstation powers it. It has eight 300 MHz R12000 MIPS processors. One processor each is devoted to each view; front, left, right, and floor. The remaining four handle (in parallel) the remaining duties such as serial data; head and mouse tracking and button input instructions. In this CAVE a user has the ability to stand within the virtual flame and suppressing agent to further analyze the interaction of these two. This simulation is only capable while immersed in the CAVE's virtual world. With a press of the virtual mouse button the observer could then control the rate at which the simulation plays out; from a single stop action frame to a continuous "real-time" rate (or any speed between) in order to study the interactions. An obvious use of this immersion is that one could put themselves in any of the seated positions and "see" the fire as the soldier would see it. The tools that were developed during this experiment will be used on current and future combat vehicle studies of fire extinguishing systems.

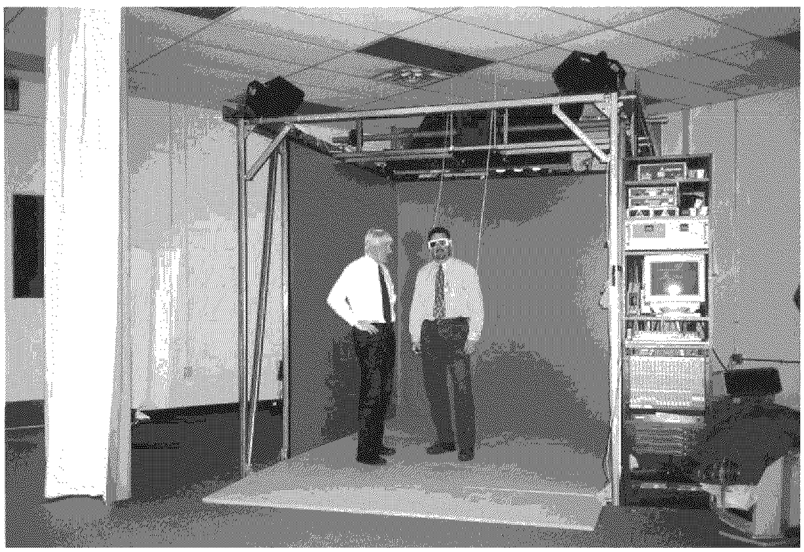

Figure 3: Dr. Blackwell and a user in the TARDEC CAVE

The Department of Defense has mandated that the replacement agent must: 1) be as effective as Halon 1301, 2) minimize space claim growth, 3) maximize use of existing hardware, 4) prevent second degree burns, 5) allow crewman to stay in the vehicle, and 5) be retrofittable. By using modeling and simulation software the engineer can more readily eliminate designs that do not meet the mandated requirements, while iteratively improving and optimizing the system to benefit the Army and most importantly, the soldier.

Paper #4
Discussor's name R. McClelland
Author Blackwell/Bochenek

Q: How effective would the display technology be in 2D in a commercial facility?

A: You of course lose the 3D, but you retain the ability to move around in the 3D CAD model. That is still a big improvement over Power Point.